PB90-256454

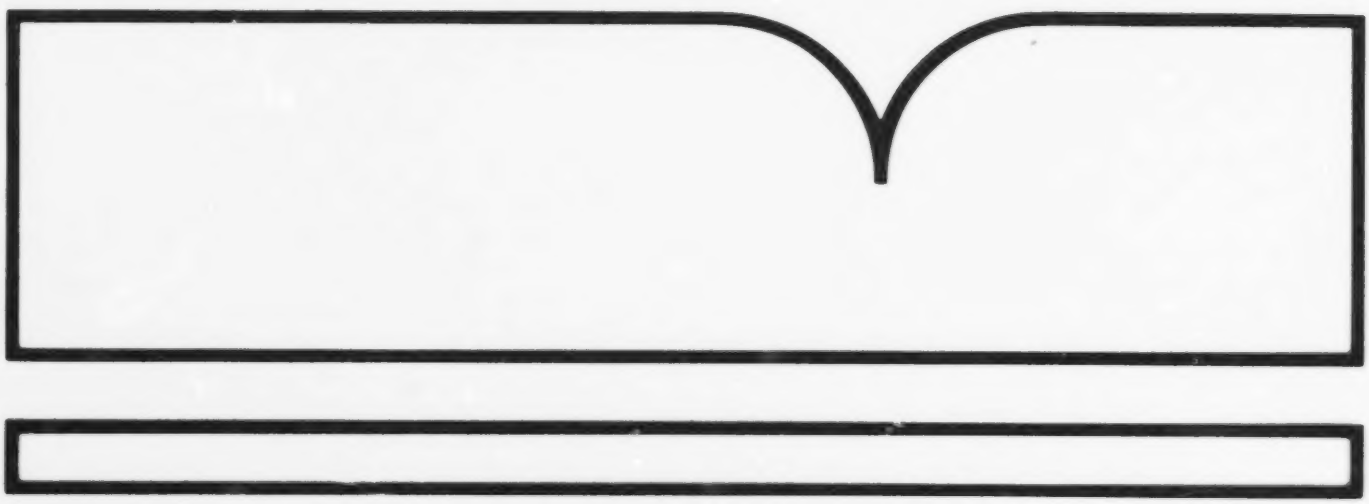
Nematicides on Florida Citrus: Pest Control in Transition

Purdue Univ., Lafayette, IN

Prepared for:

Environmental Protection Agency, Washington, DC

1989



U.S. Department of Commerce
National Technical Information Service
NTIS

PB90-256454

NEMATICIDES ON FLORIDA CITRUS: PEST CONTROL IN TRANSITION

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This report was prepared under a Fellowship Agreement with the Environmental Protection Agency's National Network for Environmental Management Studies. The author gratefully acknowledges the invaluable guidance of Bruce Sidwell of the EPA, and extends a special thanks to Harry Gaede, also of EPA, for his assistance and helpful comments on an earlier draft of this paper.

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NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

50272 - 101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/101/F-90/004	2.	3. PB90-256454

4. Title and Subtitle
Nematicides on Florida Citrus: Pest Control in Transition

5. Report Date
Completed Fall 1989

6.

7. Author(s)
Mike Habeck

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Purdue University
Department of Agriculture
Krannert Building
W. Lafayette, IN 47907

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
Office of Cooperative Environmental Management
499 South Capital Street, SW A-101-F6
Washington, DC 20460

13. Type of Report & Period Covered
Technical Report

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

4104 - Nematicides on Florida Citrus: Pest Control in Transition

The report is part of the National Network for Environmental Management Studies under the auspices of the Office of Cooperative Environmental Management of the U.S. Environmental Protection Agency.

The economic and social impacts of Environmental Protection Agency bans on the use of dibromochloropropane and ethylene dibromide for controlling Florida citrus nematodes are analyzed. Economic effects were minimal, as new nematicides were registered for the use-site. In addition, a new non-chemical cultural practice was observed. Finally, changes in the attitudes of nematode control specialists are noted.

17. Document Analysis a. Document Descriptors

b. Identifier's/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
		44
	20. Security Class (This Page)	22. Price
		A03

(See ANSI-Z39.18)

OPTIMAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

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This report was furnished to the U. S. Environmental Protection Agency by the graduate student identified on the cover page, under a National Network of Environmental Policy Studies fellowship.

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ABSTRACT

The economic and social impacts of Environmental Protection Agency bans on the use of dibromochloropropane and ethylene dibromide for controlling Florida citrus nematodes are analyzed. Economic effects were minimal, as new nematicides were registered for the use-site. In addition, a new non-chemical cultural practice was observed. Finally, changes in the attitudes of nematode control specialists are noted.

I. Introduction and Problem Statement

The problems associated with economic forecasting are not new, nor have they gone unremarked. Former Council of Economic Advisors Chairman Martin Feldstein has been quoted as saying "One of the great mistakes of the past 30 years of economic policy has been an excessive belief in the ability to forecast."[1] Kennedy (1985) quotes his colleagues as saying that economists "...only forecast to show the world that we have a sense of humor."[2] While economists (and their critics) are acutely aware of the problems associated with economic forecasting, such forecasts are a necessary part of the process of regulating pesticides.

The reason for this is that the Congress has declared them to be so. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires that "...the Administrator ... shall include among those factors to be taken into account the impact of such final action on production and prices of agricultural commodities, retail food prices, and otherwise on the agricultural economy, and he shall publish in the Federal Register an analysis of such impact."[3] before taking action to cancel a pesticide's registration or otherwise restrict its use.

Presumably, having forecasts available allows policy makers to attempt (at least) to balance the benefits and costs of various regulatory options with a greater degree of accuracy than would generally be possible with no information at all on the impacts of such action.

The purpose of this paper is to examine the economic and social consequences of selected Environmental Protection Agency (EPA) actions that restricted the use of pesticides. In addition, it looks back at predictions that were made of the economic impacts of selected regulatory actions, and compares them to the observed consequences. This is a

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[1]Time, August 27, 1984 p.46
[2]Kennedy, p.208
[3]FIFRA, Sec. 6 [136d] Administrative Review; Suspension. Par.(b)

difficult task. Nevertheless, if the benefits of pesticide use are to be properly weighed against the costs of such use, the effort must be made to improve our ability to estimate the impacts of regulatory options.

The Special Review Process

FIFRA was enacted on June 25, 1947 for the purpose of regulating "...economic poisons and devices..."[4] There have been numerous amendments to this Act, most recently in 1988. FIFRA requires that pesticides distributed or sold in the United States be registered under its provisions. It spells out the administrative procedures to be followed and the technical and financial requirements that registrants must meet in order to market pesticides. The EPA first assumed responsibility for the regulation of pesticides in 1970; previously, that function was carried out by the Department of Agriculture.

The chief administrative mechanism for cancellation or the placement of other restrictions on the registration of a pesticide, is called the Special Review process. The steps involved in this process are spelled out in the Code of Federal Regulations, Title 40 Part 154. The Administrator may decide to initiate a Special Review if he determines that the pesticide "...when used in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment..."[5] defined as "...any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide."[6]

If the Administrator decides to initiate a Special Review of a pesticide, he is required to send confidential written notice (called the Grassley-Allen notification) to the "...registrant(s) and applicant(s) setting forth his decision and a general description of the information which supports it."[7] The registrant(s) and applicant(s) have 30 days to

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[4] FIFRA, page 3
[5] ibid., p.35
[6] ibid. p.12
[7] Title 40, part 154.21 Par.(a-b)

respond. After the response period, the Administrator makes a determination whether or not to proceed with the Special Review. If, having considered the registrant's reply to the Grassley-Allen notification, EPA feels its concerns have been adequately addressed, it publishes a notice stating that it has considered and rejected conducting a Special Review for the pesticide in question, and requests public comment on the decision.

On the other hand, if the registrant fails to adequately answer the Agency's concerns, EPA may then initiate a Special Review by publishing a notice in the Federal Register. This notice, referred to as a Position Document 1 (PD/1), includes a discussion of the studies which led to the review, an estimate of likely exposures, and estimated risks. In addition, "...a preliminary benefits review has been completed to justify continued use pending a detailed risk/benefit analysis, in identifying potential regulatory options, and in preparing for a more detailed benefits analysis during the Special Review."[8] Further, public comment regarding the Special Review is invited. The EPA generally gives notice that it is requiring the registrant to provide additional information needed to clear up issues raised in the Special Review.

Having published the PD/1, the Agency undertakes a comprehensive risk/benefit analysis for each use of the pesticide. In addition, the Agency may choose to conduct meetings with interested parties to discuss Agency concerns and available options. The registrant may suggest measures for reducing risk to a level the Agency considers acceptable. If such a voluntary resolution occurs, the Agency publishes a notice so stating.

In the absence of voluntary resolution, the Agency, having completed its risk/benefit analysis and examined comments received in response to the PD/1, issues a Position Document 2/3 (PD 2/3). This document spells out the "...hazards, exposures, risks, benefits (including risks and benefits of alternatives), regulatory options, and proposed regulatory decision."[9] The available regulatory options include recommending no change

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[8] Auerbach (1986) p.3
[9] Ibid., p.5

in the regulatory status of the pesticide, cancellation of some or all uses, or other modifications in the terms of the registration. Also included in the PD 2/3 is an analysis of comments received from interested parties and the general public after the publication of the PD/1.

The PD 2/3 is made available for comment by the general public, the U.S. Department of Agriculture, and the Scientific Advisory Panel. After analysis of comments and consideration of any additional information, the EPA issues a Final Determination PD/4. The determination of Agency action becomes effective unless an adversely affected party requests a hearing. If a hearing is requested, the determination does not take effect until the completion of the hearing.

Procedures are different when the Administrator believes that imminent hazard is associated with the continued use of a pesticide. In such cases, the Administrator may issue a registration suspension order or an emergency suspension order. When a registration suspension order is issued, an expedited hearing is conducted to consider the evidence. If the hearing concurs with the Administrator's finding, the registration of the pesticide in cancelled. If the Administrator finds the hazards of continued use of a pesticide are so great that the delay imposed by a hearing is unacceptable, he may issue an emergency suspension order. Under an emergency suspension order, registration of the pesticide is cancelled immediately, although a hearing may be requested subsequently.

Analytical Approach

Waldon (1989) compared predicted and actual consequences for removal of pesticides from three use-sites: dibromochloropropane (DBCP) as a nematicide on grapes in California, nitrofen as a post-emergent herbicide on broccoli and cauliflower in California, and 2,4,5-T as a conifer release agent in the Northwestern and Southeastern U.S. Waldon

found that "...in each case, new pest management practices have evolved to replace those lost."[10]

Waldon found that in cases where a single compound was no longer available for use on a crop, innovation occurred which apparently mitigated severe adverse impacts on users. Predicted effects, though in most cases quite large, were not observed. This paper will take a slightly different approach, in that it will look at impacts on producers of a single crop that has been subject to multiple pesticide restrictions. In such cases, innovation may not mitigate effects as readily as in 'isolated' regulatory actions.

For the purposes of this study, the only pesticides considered were those which had experienced use restrictions more than five years ago. This stipulation should maximize the possibility of observing any short or long-term impacts. Since one of the aims of the paper is to compare actual consequences with those that were predicted, it was necessary to further restrict the universe of possibilities to those for which economic analyses were prepared as part of the Special Review process. Thus, compounds which were voluntarily withdrawn at a very early stage of the review process were not included.

This study looks at the impact of the cancellation of registrations for DBCP and ethylene dibromide (EDB) on oranges in Florida. These pesticides were chosen because they were both used on a single crop to control a single class of pest - nematodes. Oranges are considered to be a minor crop (by national standards, at least) and are of interest for that reason, since innovation might not be expected to occur as rapidly for minor-crop use-sites.

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[10] Waldon, p.35

II. Nematodes and Florida Orange Production

Orange production generates more revenue than any other crop grown in Florida. Florida is also the largest producer of oranges among the states, with 1985 revenues estimated at about 900 million dollars. Florida oranges have an unusually high juice content; therefore, roughly 85% are processed into orange juice. The rest are sold fresh.

Florida's orange production is concentrated in two main areas. Roughly two-thirds of citrus acreage is in the deep, well-drained sands of the central ridge. The remainder is in the low, shallow, poorly drained soils of the coastal flatwoods areas. The flatwood soils are considered less desirable for citrus production; however, the region they occur in is less susceptible to freezes than is the central ridge.

Florida citrus producers report using a wide variety of pesticides to control a myriad of pests, including nematodes (Duffy, 1985). Kaplan (1985) lists 40 plant-parasitic nematodes associated with citrus, three of which are considered to be of actual or potential economic importance. One of these is a variety of the lesion nematode, *Pratylenchus coffeae*, which is damaging to citrus but found only in a single 100 acre Florida grove. The two species of nematodes currently most important to Florida citrus production are discussed below.

The Citrus Nematode - *Tylenchulus semipenetrans*

The citrus nematode, *Tylenchulus semipenetrans*, causes the citrus disease known as slow decline. Heald and O'Bannon (1987) note that "Surveys have shown this nematode to be a pest of citrus in all citrus-growing areas of the world."[11] They maintain that since the citrus nematode "...does not devastate citrus trees, its presence may not be immediately

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[11] Heald and O'Bannon (1987) p.1

detected and the damage it does may not be easily recognized. In time, however, its effects on trees will become noticeable."[12]

Slow decline is characterized by "...a reduction in terminal tree growth... followed by reduced vigor, accompanied by yellowing and dying of leaves and twigs. The trees are not killed but produce a crop of inferior fruit."[13] Heald and O'Bannon (1987) claim that "Fruit losses from citrus nematodes in Florida may be as high as 140 boxes of fruit per acre of infested trees."[14] The citrus nematode occurs throughout Florida's citrus-growing regions, although only about 50 percent of citrus acreage is considered 'infested'. Infestation rates for California, Arizona, and Texas are 65, 90, and 50 percent, respectively (Heald and O'Bannon, 1987).

The effect of citrus nematode infestation varies considerably with soil type. O'Bannon and Esser (1985) state that "In well-drained, deep, sandy soils, citrus nematode populations on older trees may be quite high (5,000 or more per gram of root); yet such trees may show few or no decline symptoms. Conversely, in poorly drained and/or shallow soils, populations are usually lower (1,000 or less per gram of root); and tree symptoms may be quite pronounced..."[15] Thus, the citrus nematode is much more of a problem in the coastal flatwoods regions than in the central ridge.

The Burrowing Nematode - *Radopholus similis*

The burrowing nematode, *Radopholus similis*, causes a citrus disease known as spreading decline. Spreading decline is known only in Florida, and only in the deep, sandy soils of the central ridge portion of the state. While burrowing nematodes have been detected in every citrus-producing county in Florida (Kaplan, 1985), the symptoms of spreading decline are much less severe in the flatwoods regions. In 1976, approximately

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[12] Ibid., p.1
[13] Poinar (1983) p.141
[14] Heald and O'Bannon (1987) p.1 In Florida, one box of oranges weighs 90 pounds; thus Heald and O'Bannon are claiming a loss of up to 12,600 pounds of fruit per acre.
[15] O'Bannon and Esser (1985) p.1

5700 acres of Florida citrus were considered to be 'infested' with burrowing nematode (Baines, van Gundy, and DuCharme, 1978). Spreading decline is characterized by "...stunted trees that produce reduced, poor quality fruit."[16] Poinar (1983) claims that "...spreading decline of citrus cost Florida growers millions of dollars and a production loss of several thousand acres."[17]

Burrowing nematodes occur almost exclusively below 30cm in the soil profile. Noling (1989) has said that up to 90% of the roots below 30cm can be killed outright. The nematodes are considered poor competitors and give way to populations of other soil organisms that invade necrotic roots. In doing so, they migrate along roots, and can travel up to 100 feet a year, although a more typical rate is 25-50 feet annually. This characteristic gave rise to the term "spreading decline".

Since citrus roots are very extensive, often extending 75 feet from the center of the tree, control of the burrowing nematode is extremely difficult. Barriers such as railroad right-of-way, highways, and small streams cannot be relied upon to impede the progress of the nematode. In addition, the host range of the burrowing nematode is very wide. It is able to subsist on the roots of many weeds, as well as those of deciduous and evergreen fruit trees.

In the 1950s, the State of Florida, through the Plant Industry Division of its Department of Agriculture, tried to control the spread of burrowing nematodes by establishing a barrier program. They undertook a sampling program to determine the extent of the infestation, uprooted thousands of trees, and created weed-free barriers no less than 50 feet wide that separated infested areas from those that were threatened. In addition, 5 foot trenches were dug on each side of the barrier, with the intention of destroying roots.

EDB was heavily used in the control barrier program. Not only did the EDB kill nematodes, it also, as a result of its phytotoxicity, killed roots in the barrier zone. The lack

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[16] Poinar, p.137
[17] Ibid., p.138

of roots in the barrier prevented the spread of nematodes. EDB was chisel injected in the barrier zones every six months at rates of 25 gallons active ingredient per acre during the course of the barrier program (1961-1983).

III. Dibromochloropropane (DBCP)

1,2-Dibromo-3-chloropropane (DBCP) is a volatile, dark brown liquid. Its nematicidal properties were first noted by McBeth and Bergeson (1955). It is relatively non-phytotoxic, a property which makes it suitable for postplant control of nematodes. Its major use was as a soil fumigant, employed to control nematode populations on soybeans, pineapples, peaches, grapes, and citrus. The major producers of DBCP in the United States were the Dow Chemical Co , which marketed DBCP under the tradename Fumazone™, and the Shell Development Co., which used the tradename Nemagon™.

In Florida, DBCP was used in post-plant situations as a means of controlling the citrus nematode. The first use of DBCP in Florida for that purpose was reported by Hannon (1964). DBCP was applied primarily by means of tractor-drawn chisel applicators, with injection occurring at a depth of about eight inches (USDA/State and EPA, 1977). Alternatively, "...DBCP can be applied through aluminum irrigation pipe, laid on the ground between rows of citrus trees. Because labor cost of moving irrigation pipe is constantly increasing, this method of irrigation is being replaced by permanent overhead irrigation. DBCP cannot be applied economically by overhead irrigation, because too much DBCP is lost from volatilization. Consequently, only about 10% of the DBCP is applied where ground pipe irrigation is still practiced."[18]

Application rates depended on soil texture. In finer textured soils, as much as 60.5 pounds of DBCP per acre was recommended, while in coarser textured soils, the recommended rate was 36.3 pounds per acre. A single application of DBCP was generally effective for three years. During the preparation of EPA's preliminary benefits analysis, the price of DBCP was found to range between $6 and $13 per gallon, with each gallon containing 12.1 pounds of active ingredient. Therefore, the cost per acre ranged from approximately $18 to $65.

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[18] USDA/State and EPA Cooperative Assessment of DBCP Uses in Agriculture, p.39

Regulatory History of DBCP

On September 8, 1977, the EPA Administrator determined that suspension of the registration of products containing DBCP was necessary to prevent 'imminent hazard'. The Administrator issued a Suspension Order for DBCP products on October 27, 1977, accompanied by the "Notice of Intent to Cancel the Registrations or Change the Classifications of Pesticide Products Containing Dibromochloropropane (DBCP)" required by FIFRA.

"Following the publication of the Administrator's Notice of Intent to Suspend, a DBCP Impact Assessment Team was appointed by the National Pesticide Impact Assessment Steering Committee..."[19] as provided for in an EPA agreement with USDA. "The Assessment Team's membership included representatives from both the Agency [EPA] and USDA, as well as State Extension Service and research personnel knowledgeable in the field of nematode damage and control."[20]

The Cooperative Assessment Team produced a report, "*USDA/State and EPA Cooperative Assessment of DBCP Uses in Agriculture* ". The report included discussion of such factors as application methods, availability of chemical and non-chemical alternatives for nematode control, and the economic consequences of DBCP cancellation. "When information was not available, Assessment Team members, relying on their collective experience and expertise in the fields of nematology and agricultural practice, developed consensus estimates of yield or quality impacts which would result from the cancellation of DBCP."[21]

The Cooperative Assessment was reviewed by economists from EPA and USDA, who undertook additional data-gathering from university, extension, statistical, and user sources. The revised and extended document was used in producing EPA's final analysis

[19] DBCP Final Position Document, p.45
[20] Ibid., p.45
[21] Ibid., p.47

of DBCP benefits, "Economic and Social Impacts of Cancelling Use of DBCP as a Pesticide for All Registered Use Sites with Known Current Usage."

On August 11, 1977, the Dow Chemical Co. halted production and sales of DBCP. The next day, the California Department of Agriculture announced the suspension of all sale and use of DBCP. On August 25, 1977, Dow announced the recall of DBCP from users and distributors. Shell Development Co. announced its own recall on August 26, 1977. Prior to the cancellation of its registration, DBCP was used in 72 Federal and 95 State registered products manufactured or formulated by 63 different companies.

EPA's Economic Analysis of the Impacts of Restrictions on DBCP Use on Citrus[22]

The analysis considered two scenarios: complete availability of DBCP, and immediate cancellation of DBCP use on citrus. Only immediate yield impacts over a three-year horizon were considered, although the report acknowledged that tree longevity might be halved without adequate nematode control. Likewise, impacts on fruit quality or grade were not considered, even though "Numerous DBCP field studies of citrus have shown that the use of this material leads to an improvement in the grade of fruit produced by treated trees relative to untreated trees." (p.2-2) Longevity and fruit quality impacts were not specifically addressed because of wide variation in observed effects. Estimates of use levels (both in terms of acreage and quantity) were provided by local experts; so were yield impact estimates. It was assumed that a given level of yield impact would occur on all acres treated with DBCP if registration was cancelled.

DBCP was used primarily to control the citrus nematode, which was estimated to infest 53% of Florida citrus groves. O'Bannon was cited in the report as saying that despite the extent of infestation, relatively few growers treated their citrus crops with DBCP. He attributed this to two main reasons. First, growers associated nematode-

[22] All material in this section has been taken directly from "Economic Analysis of DBCP Use on Citrus" in "Economic and Social Impacts of Cancelling Use of DBCP as a Pesticide for All Registered Use Sites with Known Current Usage."

induced loss of tree vitality with other causes, especially lack of water or nutrients, or to damage from other pests. Secondly, growers simply were not aware of the benefits of DBCP treatment, or felt that their nematode problem was not serious enough to warrant treatment. Of a total of 796,200 bearing acres of citrus in Florida in 1976, an estimated 421,986 acres were infested with citrus nematodes. Of these, only 9,000 acres were under treatment with DBCP.

Soil injection using tractor-drawn chisel injectors was the preferred method of DBCP application in Florida. Ninety percent of DBCP was applied in this manner; the remainder was applied via ground pipe irrigation. However, chisel injection had the disadvantage of causing extensive damage to near-surface roots. DBCP was used on a three-year schedule. After each application, nematode populations were suppressed (up to 99% of nematodes killed) and populations took 3 to 4 years to recover to damaging levels.

Florida growers were estimated to incur per acre revenue reductions of about $109 to $188. Although the report does not explicitly say so, this impact presumably applies only to producers who were using DBCP. The majority of growers, who were not using DBCP, would presumably have suffered no negative impact from cancellation. In fact, if the quantity of oranges fell enough to cause an increase in orange prices, the majority of growers would receive higher prices with no change in their output. This would mean that the revenues of non-user growers would be higher as a result of cancellation.

The report maintains that gross revenues of Florida orange growers would fall by $317,000 in the first year after DBCP cancellation. The cumulative impact for the first three years after cancellation, with discounting at 7 percent annually, was $1,626,400. The loss to Florida orange growers in the third year after cancellation was estimated to be $776,300, compared with total Florida crop value of $639,877,000.

Because of wide variations in conditions, no attempt was made to estimate the effect of DBCP cancellation on the 'average' Florida citrus grower. However, an example was provided of the impact felt by an orange grower suffering from 100% citrus nematode

infestation after DBCP cancellation. In the example, DBCP use was assumed to result in a 16.7% increase in yield. Management costs dropped from $370 per acre to $346 per acre as a result of cancellation; however, revenues also fell from $739 to $633 per acre. The result was a drop in per-acre net returns from $369 to $287 per acre, a decrease of $82 per acre, or 22 percent.

For orange growers nationwide, the report predicted production losses of 4.60% and 0.17% for fresh and process oranges, respectively. The report states that the projected yield reductions are probably worst-case, since prices would increase, encouraging expansion of acreage in production. These higher prices would result in revenue gains to non-users of DBCP, and offset losses to users. The report did not include an estimate of these grower price effects because of price uncertainties caused by weather and other factors. However, consumers were expected to pay 3.83% more for fresh oranges, with little price effect predicted for processed orange products.

The report emphasized that while short run impacts would consist of immediate yield reductions, the greatest long term impact would be on tree longevity. With productive tree life predicted to drop from 60 years to 30 or 40 years after DBCP cancellation, earlier replanting would be necessary, along with four years of unproductive acreage.

IV. Ethylene Dibromide (EDB)

Ethylene dibromide (or more correctly, 1,2-dibromoethane, but hereafter referred to as EDB) is a dense liquid with both insecticidal and nematicidal properties. The great majority of EDB produced in the United States is used as an additive in leaded gasolines, though this use is declining as leaded gasolines are phased out. EDB also found substantial use in agricultural applications. Probably the most important of these was in the post-harvest fumigation of grains, fruits, and vegetables. The Dow Chemical Co. introduced EDB in 1946 under the tradename Bromofume™. In 1980, there were four major EDB producers in the United States: Dow Chemical, Ethyl Corp., Great Lakes Chemical, and PPG Industries. Slightly less than four percent of the estimated annual production of 350 million pounds was used for soil fumigation.

EDB is highly phytotoxic, so its nematicidal uses are necessarily restricted to preplant situations. It has been reported as an effective agent in the control of the citrus nematode (O'Bannon and Tarjan, 1973), were it provided control of the citrus nematode for at least four years after pre-plant application. EDB's most important application in nematode control in Florida was as the key ingredient in the combined USDA/State barrier program to control the spread of the burrowing nematode. It was especially effective for this purpose, since it kills the roots that burrowing nematodes need for sustenance and dispersal.

EDB was typically applied to soil known to be infested with nematodes before setting new citrus trees. Application involved chisel injection of 180 pounds of active ingredient per acre at a depth of about 10 inches. A roller was used to reseal the soil after injection, thus minimizing volatilization. In Florida, EDB was used by growers in preplant situations on only about 110 acres per year, or roughly one percent of new plantings. The most important use was in the barrier control program described earlier.

Regulatory History of EDB

EPA Administrator William Ruckelshaus issued an emergency order suspending registrations of products containing EDB on September 28, 1983. The order noted that EDB had been found to be "...a potent cancer-causing agent..."[23] , which "...induced tumors in both sexes of mice and rats, by all routes of exposure (oral, inhalation, dermal)."[24] In addition, the order observed that "...soil fumigant uses of EDB are likely to result in leaching to groundwater and, therefore, in contamination of human drinking water sources."[25] , and that "Because of the persistence of EDB in soil and water, contamination is expected to endure long beyond the period of use."[26]

Prior to the emergency suspension, 53 registrants held 122 federal pesticide registrations and 12 registrants held 24 state registrations of products containing EDB as an active ingredient.

EPA's Economic Analysis of the Impacts of Restrictions on EDB Use

The Benefits Analysis for EDB usage was done jointly by economists from EPA and USDA and presented in a report entitled *Abbreviated Benefits Analysis of Pesticide Uses of Ethylene Dibromide*. Most of what follows is taken from that document.

In 1978, a USDA/State and EPA Cooperative Assessment Team (similar to that employed in the DBCP Benefits Analysis) made estimates of annual EDB usage. However, DBCP was largely banned in 1979. "This most likely resulted in some increase in EDB usage for certain sites. Because it was not possible to determine the magnitude of these increases, the original 1978 estimates of annual usage were used as a base for most of the sites analyzed."[27]

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[23] US EPA (1983) p.11
[24] Ibid., p.11
[25] Ibid., p.12
[26] Ibid., p.12
[27] Ethylene Dibromide Position Document 2/3 p.68

Although EDB and DBCP were used to control the same nematodes, EDB was used exclusively for preplant fumigation (due to its phytotoxicity). While DBCP could be used in preplant situations, virtually all application was for postplant nematode control. Thus, the two compounds were not exact substitutes and the assumption made by the assessment team was an appropriate one for citrus.

EDB use on Florida citrus in 1977 was estimated at 20,000 pounds active ingredient, a quantity suitable for treating approximately 110 acres. About 14,000 acres were set annually in the late 1970s, indicating that less than 1% of new citrus acreage received preplant treatment with EDB. The second and probably most important use of EDB on citrus was in the barrier establishment and maintenance program to contain the spread of burrowing nematodes in Florida. Treatments were performed every 6 months; total annual EDB usage by the program was about 252,000 pounds active ingredient.

Citrus growers utilizing EDB for preplant control of citrus nematodes were predicted to be unlikely to experience significant changes in levels of control following adoption of D-D™ or Telone™[28] . However, the use of these materials would increase treatment costs considerably. The per acre cost of treatment with EDB was approximately $82.50 ($5.50/gallon of 84.5% EDB x 15 gallons/acre) compared with $100/acre with D-D™ ($2.50/gallon x 40 gallons/acre) and $128/acre with Telone™ ($4.00/gallon x 32 gallons/acre). Thus, the use of D-D™ or Telone™ was expected to increase per acre treatment costs by $17.50 (21%) and $45.50 (55%) respectively. The use of D-D™ and Telone™ in place of the 20,000 pounds EDB active ingredient applied to 110 citrus acres in 1977 would increase grower treatment costs by a total of about $3,500 annually ($31.50/acre average cost increase x 110 acres). Application costs would also rise due to the increased quantities required for treatment when D-D™ and Telone™ were used. The higher application rates for D-D™ and Telone™ compared to EDB would also increase

[28] These nematicides were considered to be the most likely alternatives to EDB. They are discussed in more detail in Section VI of this paper.

transportation and handling costs appreciably. Lack of information prevented quantification of the costs of these logistical problems.

The USDA-State barrier program for burrowing nematode containment was expected to utilize D-D™ and/or Telone™ in the event EDB were unavailable. It was considered likely that the program, which used EDB at a rate equivalent to 25 gallons per acre, would also require greater-than-normal quantities of D-D™ and/or Telone™ on an area basis. Assuming that the percent increase in gallons of EDB applied for this use relative to the normal preplant application rate could be applied to determine the required gallons of D-D™ and Telone™, 67 gallons of D-D™ or 53 gallons of Telone™ would be required per surface acre. The per acre costs of treatment with EDB, D-D™, and Telone™ at the increased rates were calculated to be $137.50, $167.50, and $212.00 respectively. The area treated with EDB twice annually represented the equivalent of approximately 840 acre-treatments. Thus, the use of D-D™ and Telone™ in this capacity would increase the program costs from $25,000 to $63,000 per year, depending upon whether D-D™ or Telone™ were used in place of EDB. As in the case of preplant use of EDB, the report noted that adoption of D-D™ or Telone™ in the burrowing nematode control program would increase transportation and handling costs due to the increased volume of required materials, but did not attempt to quantify these increased costs.

The use of D-D™ or Telone™ in place of EDB was not expected to create impacts other than control cost increases. Since EDB use for citrus nematode control was very limited, and since no significant quality or yield effects were associated with the use of Telone™ or D-D™, the cost effects resulting from the loss of EDB for preplant citrus use would be absorbed at the grower level, with no market or consumer impacts anticipated.

The loss of EDB for use in the burrowing nematode control program was predicted to have implications beyond the relatively small cost increases associated with the use of Telone™ or D-D™. Control was reported to be better with EDB in soil types and temperatures encountered in the program area. EDB was more effective as a 'root pruning'

agent. Reduced control levels could lead to a further increase in the range of the burrowing nematode in Florida citrus groves, resulting in the problems associated with spreading decline. Expansion of this disease over a period of years could lead to significant declines in citrus yield and quality, barring the introduction of an effective nematicide or other control agent.

Growers affected by the spreading decline problem could be expected to abandon declining groves and establish new ones in non-infested areas or get out of the business. In the longer term, if unsolved, the burrowing nematode-spreading decline effect could reduce citrus supplies to the point were consumers would begin to be affected by higher retail prices and/or reduced quality of citrus and citrus products. However, the report maintains that this situation would be alleviated by plantings in non-infested production areas and/or introduction of new control materials or techniques. Such price impacts could also be mitigated by increased imports of citrus products into the U.S.

V. Economic Impacts of DBCP & EDB Restrictions

Figure 1 illustrates prices received by Florida orange growers during the period 1970-1986. Prices are in dollars per box, and have been adjusted for inflation in the producer price index. Thus, all prices are expressed in terms of 1970 dollars.

It is difficult to draw any conclusions from this diagram. Certainly, there are large year-to-year variations in prices received by growers. It could also be argued that prices are showing a gradual upward trend. However, it would probably not be reasonable to attribute these movements to regulation.

A more plausible cause of price variation in Florida citrus is the weather. In particular, freezing weather, which adversely affects production. Florida growers experienced freezing weather of sufficient duration and intensity to adversely affect citrus production during the periods January 17-22, 1977; January 12-13, 1981; January 11-14, 1982; December 24-25, 1983; January 21-22, 1985; and January 27-28, 1986 (Florida Division of Plant Industry, 1989). Several of these freezes damaged or killed thousands of citrus trees.

Freezes have been responsible for the major change in the Florida citrus industry during the 1980s: the virtual abandonment of many groves in the northernmost growing regions of the state. Primarily as result of freezes, Florida citrus acres dropped from 845,263 to 624,492 during the period 1980-1986 (FCLR, 1986). The loss of roughly one fourth of Florida citrus-producing acreage might easily have been responsible for any observed upward trend in prices.

While freeze damage has been the single most important factor in reducing citrus acreage, other causes exist. Florida has experienced a tremendous increase in population in the past twenty years. The result has been the loss of agricultural land (including land in citrus) to other uses. Many trees were destroyed in the early to mid eighties when

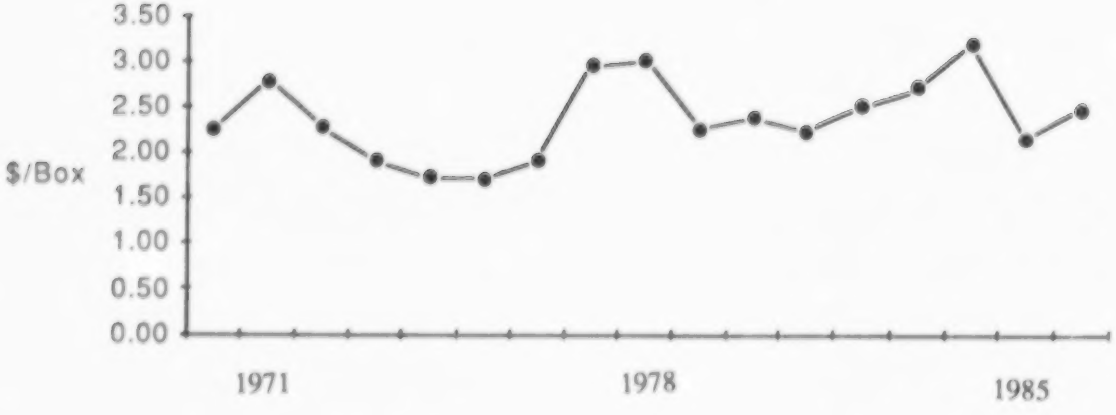

Figure 1: Average Price Received by Florida Orange Producers for the Years 1970-1986 (1970 dollars)

they were found to be infected with citrus canker. Clearly, regulatory activity has played a very small part in any reduction of supplies and consequent price increases.

A consistent set of retail price data could not be found for an analysis of the citrus consumer price impacts. The impact of DBCP and EDB loss on consumer prices was predicted to be negligible. Large increases in consumer-level citrus product prices have, however, been observed following freezes, and it would seem reasonable to assume that weather plays a dominant role here as well.

Figure 2 illustrates how the U.S. and Brazilian shares of the world Frozen Concentrated Orange Juice (FCOJ) market have changed over the period 1978-1986. Because of inconsistencies in the data and a change in reporting methodology, comparable information on market shares before 1978 was not available. However, overall trends seem evident for the market shares of both countries.

The benefits analysis did not directly address the question of competitiveness of U.S. producers in world markets, so there are no predictions to compare with outcomes. In any case, Brazil already dominated world FCOJ markets before the cancellation of DBCP. Whether regulatory action made the U.S. growers' market position worse relative to that of Brazilian producers is virtually impossible to say. Detailed information on regulations (if any) facing Brazilian citrus producers was not available.

If Brazilian producers have available a set of nematode control options greater than that of U.S. producers, then they should enjoy some incremental degree of competitive advantage as a result. How great that advantage might be, and what other factors affect comparative advantage in citrus production, are unknown.

Waldon (1989) found that new management practices were developed to replace those lost as a result of regulation. The same occurred in the case of the registration cancellations of DBCP and EDB. In both cases, new nematicides were registered that provided similar levels of control, albeit at higher prices. The citrus nematicides currently available and in use are described in section VI of this paper.

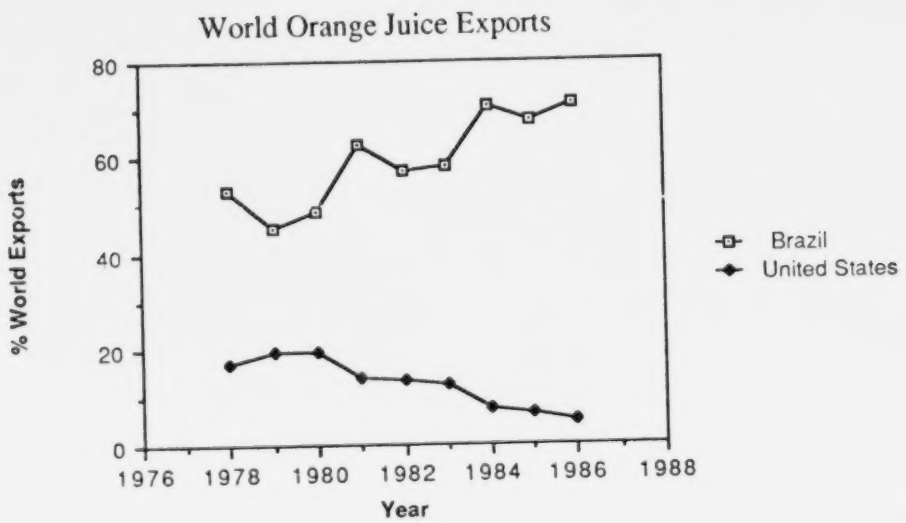

Figure 2: U.S. and Brazilian Shares of the World Frozen Concentrated Orange Juice (FCOJ) Market, 1978-1986.

Recent efforts to control the damage done by burrowing nematodes have taken a non-chemical approach. When EDB lost its registration in 1983, the barrier control program was discontinued. Extensive groundwater contamination has occurred in areas treated with EDB as part of the barrier program. As a result, the program has become highly controversial and issues related to its operation are now being resolved in the courts.

While the State of Florida has not been active in maintaining burrowing nematode barriers, some growers have continued attempts at controlling the spread of burrowing nematodes by trenching (to destroy roots), keeping barrier zones weed-free, and application of registered nematicides. A sampling program is under way to determine whether burrowing nematodes have begun to breach the old barrier system.

The loss of DBCP and EDB registrations, as well as ongoing Special Reviews for several other nematicides, seems to have created greater interest in non-chemical controls. The dream of eradication appears to be giving way to a "learning to live with nematodes" management approach. This is particularly true in the control of burrowing nematodes.

Changes in management practices have led to a marked improvement in the ability of Florida citrus trees to withstand the attack of burrowing nematodes. As noted earlier, burrowing nematodes attack only those roots 30cm or deeper in the soil profile. The damage to attacked roots is considerable. However, it has been found that citrus trees are able to survive burrowing nematode depredation given changes in production practices.

When the deeper roots of a citrus tree are destroyed by burrowing nematodes, it must rely on roots nearer the soil surface for water and nutrient uptake. Disking for weed control results in extensive damage to roots close to the surface, and during periods of low rainfall, the combination of damaged roots near the soil surface and burrowing nematode damage to deeper roots creates water stress in the plant, leading to early fruit drop. Using herbicides to control weeds eliminates the need for disking and allows roots near the soil surface to grow undisturbed.

Nevertheless, during low rainfall months, trees may still be stressed. Therefore, extension experts in Florida recommend extensive irrigation during periods of low precipitation. Since trees under burrowing nematode attack must rely on roots near the soil surface, this soil must never be allowed to completely dry out. The combination of herbicide use for weed control and irrigation appears to be successful in controlling the effects of the burrowing nematode, and highlights the importance of understanding the complete crop production process, rather than individual pest-crop interactions.

In summary, technological innovation has occurred in the wake of DBCP and EDB registration cancellations, both in the use of new nematicides and cultural practices. The prospect of further restrictions on nematicide use also seems to be leading to a change in attitudes and approaches in nematode control. Nematode control experts are not happy about losing chemical controls that work. However, they are adapting to the new regulatory environment.

VI. Practices and Prospects for Nematode Control

A wide variety of techniques have been proposed for the control of nematodes, from saturation of the soil with boiling water and electrocution (see, for example Caveness and Caveness, 1970) to more conventional techniques like chemical control, biological control, host resistance, and integrated pest management. The latter options are briefly discussed in this section of the paper.

Chemical Control of Nematodes

Citrus nematicides may be classified into three basic types: seedling root dips, preplant, and postplant nematicides.

Seedling root dips are used in citrus nurseries to produce nematode-free root stocks. These nematicides are used in relatively small amounts and are not applied directly to soils. Therefore, they are not of great concern from an environmental contamination perspective, although applicator exposure might be a concern. The principal citrus seedling root dips are fensulfothion (marketed by Bayer AG under the tradename Dasanit™), and ethoprop (marketed by Rhone-Poulenc under the tradename Mocap™). Mocap™ may also be used as a pot drench in seedling nurseries. Both are effective in controlling nematodes.

1,3-Dichloropropene is the nematicide currently favored by Florida citrus growers who treat preplant (Heald and O'Bannon, 1987). However, only about 10% of new acreage is treated (Noling, 1989). Two nematicides containing 1,3-dichloropropene, Telone™ and D-D™, were the nematicides that the USDA/State and EPA Cooperative Assessment Team predicted would replace EDB.

D-D™ is a mixture of 1,3-dichloropropene and 1,2-dichloropropane marketed by Shell Development Co. An identical product was marketed by Dow Chemical Co. under the tradename Vidden-D™. The companies voluntarily halted production of D-D™ and Vidden-D™ following the initiation of a Special Review for 1,3-dichloropropene.

A variety of products containing 1,3-dichloropropene are still available; many are formulated with other compounds that provide different kinds of pest protection. Telone™ was introduced by Dow Chemical Co. in 1956. It is currently marketed by Dow as Telone II™ (containing 94% 1,3-dichloropropene) and Telone C-17™ (74% 1,3-dichloropropene and 16.5% chloropicrin[29]). Vorlex™ (produced by Nor-Am Corp.) contains 40% 1,3-dichloropropene and related C3 hydrocarbons as well as 20% methylisothiocyanate (MITC).[30]

As mentioned earlier, 1,3-dichloropropene is currently under Special Review. It has been identified as an oncogen, and 1,2-dichloropropane, an unavoidable byproduct of the manufacturing process which is present in the commercial product, is also an oncogen. While 1,3-dichloropropene degrades fairly rapidly in soils, 1,2-dichloropropane does not, and it has been found in groundwater samples from at least five states (EPA, 1986). A PD 2/3 on 1,3-dichloropropene is scheduled for completion in fiscal year 1990.[31]

Aldicarb is a systemic nematicide which may be used in both preplant and postplant situations. It also provides control of certain mites and insects. It is produced by Rhone-Poulenc under the trademark Temik™. Aldicarb is considered to be the most likely alternative to 1,3-dichloropropene in Florida, although it is considered somewhat less effective in some crop situations.

Aldicarb is granular, so it requires different application equipment than that used to inject EDB or 1,3-dichloropropene. It also requires irrigation or rainfall after application before it is activated. It has lower material costs per acre than Telone™ ($83 vs $230-460)[32] , but this must be offset against the need for irrigation and lower efficacy.

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[29] Chloropicrin has fungicidal properties.
[30] Effective against fungi and weed seeds.
[31] Pesticide & Toxic Chemical News, June 21, 1989 p.16
[32] EPA (1986)

Aldicarb is also involved in the Special Review process. It is acutely toxic to mammals and has been found in ground or drinking water wells in 16 states.[33] EPA is scheduled to release a Position Document 2/3 for Aldicarb in February, 1990.[34]

Methylbromide is the only other preplant nematicide which is considered to be comparable to 1,3-dichloropropene in effectiveness. However, it is more expensive than 1,3-dichloropropene, and time-consuming to use. It is applied using an injector-probe which must be inserted into the soil at each tree site. Noling (1989) believes that methylbromide is not likely to be adopted by Florida growers because of concerns about liability and groundwater contamination. Methylbromide is also extremely poisonous to humans, thus applicator exposure is a concern.

Other preplant nematicides include sodium methyldithiocarbamate (SDMC), oxamyl, and fenamiphos. None are considered as effective as 1,3-dichloropropene, aldicarb, or methylbromide in controlling citrus nematodes. Only fenamiphos is widely used in Florida. SDMC (also known as metam or metham-sodium) is marketed under the tradename Vapam™ by ICI Americas Inc. It is registered for use only on non-bearing citrus. Oxamyl is marketed by DuPont under the tradename Vydate L™. It is a systemic nematicide which, like SDMC, is registered for use only on non-bearing citrus. Its effectiveness varies tremendously (see Baines and Small, 1976); it seems to be much more effective in Texas than in Florida. Oxamyl is extremely toxic to mammals and has been found in drinking water in at least two states. EPA decided as of June 1987, not to place oxamyl under Special Review, though data on some of its impacts were still unavailable (EPA, 1987).

Fenamiphos is a systemic nematicide marketed by Mobay Corp. under the trademark Nemacur™. It is suitable both for use on preplant and postplant citrus and is the principal alternative to aldicarb for postplant nematode control of Florida citrus. Approximately 40%

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[33] EPA (1988) p.ii
[34] Pesticide & Toxic Chemical News, June 21, 1989 p.15

of Florida citrus producers treat postplant for nematodes; virtually all of that involves the use of aldicarb or fenamiphos (Noling, 1989). Because the use of aldicarb has caused groundwater contamination problems, fenamiphos is the postplant citrus nematicide recommended by the State of Florida. However, fenamiphos usage is lower than that of aldicarb, since aldicarb is less expensive and considered to be more effective.

Biological Control of Nematodes: Practices and Prospects

Veech (1981) has noted that "...in nature, most plants are resistant to most nematodes. Generally, that resistance is manifested at the preinfection stage. However, we usually dismiss this situation and refer to such plants as nonhosts. But what is there about these nonhosts that makes them less desirable to a nematode than host plants? Unfortunately, we do not have an answer to this question because our attention is usually directed to those plants that are attacked by parasitic nematodes."[35]

Numerous nematode-resistant citrus rootstocks have been developed over the years. However, despite the intense activity directed toward the development of such rootstocks, and their subsequent widespread use, the nematode problem has by no means been solved. The reason is summed up by Poinar (1983): "When resistance is bred into a crop, it is often followed, sooner or later, by the appearance of new nematode 'pathotypes' capable of breaking the resistance."[36]

Citrus trees are expected to have a productive life of about 60 years. Unfortunately, citrus rootstocks have not been able to demonstrate resistance for nearly as long. Because nematode life cycles last 6-8 weeks, new nematode races can appear relatively quickly. O'Bannon and Esser (1985) discuss an especially successful citrus rootstock that demonstrated resistance to burrowing nematodes for nearly 10 years. Where nematode-resistant citrus rootstocks are concerned, time is on the side of the nematodes.

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[35] Veech (1981) pp. 377-378
[36] Poinar (1983) p.278

Biological control has been suggested as a way of controlling nematode populations. Biological control systems, once set up, may be relatively self-sustaining in comparison with chemical systems. Mankau (1981) states that "Biological control is an attractive alternative to pesticides that needs development and greater emphasis. The increased interest in control systems which integrate all available methods against pest problems is promising, but some of the greatest difficulties in developing an integrated control program for nematode pests are the scarcity of selective chemicals and the paucity of knowledge about the biology and occurence of natural enemies, especially microbial agents.

"Nematodes, which are second only to insects as major invertebrate pests of plants, appear to have many types of microbial antagonists in common with insects, although by present knowledge not nearly as abundant in number and diversity. The latter fact may be due, in part, to the small number of researchers actively seeking such organisms."[37] Mankau also says that "There is not a single commercially important, biological control practice based on microbial agents currently in use against nematodes."[38]

Integrated Nematode Management: Practices and Prospects

According to Bird (1981), Integrated Nematode Management (INM) "...seeks to stabilize populations of target nematodes at acceptable levels."[39] Bird identifies three major components of an integrated nematode management program: exclusion, population reduction, and tolerance.

Exclusion involves preventing the spread of nematodes to unaffected areas. There are a number of techniques used to achieve this goal, among them being quarantines, the use of certified plant material, and nematode-free soil and planting equipment. Population reduction is the goal of nematicides and biological control. Bird points out that "Eliminating established nematode populations is not feasible in most agricultural

[37] Mankau (1981) p.476
[38] Ibid., p.475
[39] Bird (1981) p.356

production systems."[40] Tolerance is the aim of using nematode resistant rootstocks, and the development of production practices that minimize the deleterious effects of nematode infestation.

[40] Ibid., p.366

VII. Policy Issues

Prospects for Nematicide Innovation

The development of a successful nematicide presents special problems to potential manufacturers. Nematode species are quite varied; so a nematicide which is to be effective must have broad-spectrum action. This lack of specificity means that nematicides often reduce populations of non-target organisms along with the nematodes they were intended to kill. Because nematodes are generally present in vast numbers, eradication is impossible; simple control requires heavy application rates.

Since nematodes are scattered throughout the soil profile, an effective non-systemic nematicide must be able to move through the soil with ease. When coupled with the high application rates and high groundwater tables, this characteristic can easily lead to groundwater contamination. For systemic nematicides, the possibility of food residues creates a whole new set of problems. Data must be developed on the transport of nematicides into edible portions of the crop, and the likely human health consequences of probable exposure.

Groundwater Contamination

The extent of groundwater contamination and the seriousness of any consequences to human health are poorly understood. There are many reasons for this. The effects of many groundwater contaminants on human health are uncertain, which makes it impossible to decide what level of contamination is 'safe'. The concept of safety must take into account the existence of subpopulations which may be more susceptible to the deleterious effects of groundwater contamination than the population as a whole. Infants and children are of particular concern; however, persons suffering from a variety of ailments may suffer harm from levels of contamination that would leave a healthy person unaffected.

There is the problem of deciding what levels of contamination actually exist in the groundwater. Monitoring efforts are increasing but expensive and still in the preliminary stages. Very little background data exist to show whether or not problems are new, continuing, getting better, or getting worse. Measurements made in the past may not be comparable with contemporary measurements due to advances in the techniques of analytical chemistry. Further, water which is today considered clean may be found to contain chemical contamination as new compounds are looked for and detection limits continue to move lower and lower.

Because of the uncertainty over the extent and effects of groundwater contamination, policy options are controversial. It is not clear how citrus producers will be affected. Restrictions (on rates, formulations, areas of use) may be sufficient to provide an acceptable level of groundwater contamination. On the other hand, should currently popular nematicides lose their registrations, producers will have to find other means of nematode control. Possibilities include biological control, integrated pest management, and changes in cultural practices. In addition, pesticide manufacturers may attempt to develop new chemicals to replace those lost.

Minor Crop Issues

One of the major concerns expressed about EPA's regulation of pesticides is the impact it may have on producers of minor crops. The development of new pesticides is a lengthy and expensive process. It has been estimated that "About 23,000 new compounds are now screened for each new pesticide discovered..."[41] When a promising compound is discovered, it must be tested on the appropriate crop(s) and pest(s) to ensure that it is effective.

If the compound works, and the manufacturer wishes to market it, the compound must go through the registration process. As part of the registration process, new pesticides are

[41] NACA (1986) p.9

tested to see if they are acutely toxic to non-target organisms or exhibit carcinogenic, mutagenic, or teratogenic properties. In addition, information is collected about the compound's likely ecological impact and environmental fate. These testing requirements add to the time and money costs of development.

Once a compound is registered, the registrant must incur additional costs in order to manufacture, market, and distribute the new product. Most of these costs are incurred well before any sales revenue is received. Of course, there is no guarantee that a new product will win acceptance with farmers. Furthermore, patented products may spend much of their patent life in the development/regulatory process.

Given that a very large investment must be made in the development and registration or a new pesticide, it behooves the manufacturer to make sure that the potential market for the pesticide is large enough to allow recovery of costs, not to mention profits. When the potential market for a pesticide is too small to allow a pesticide developer to (at least) recoup costs, development of new pesticides for that market would not normally be expected to occur.

There are four basic potential problem situations facing producers of minor crops. The first involves a suitable chemical already registered for a major crop which cannot be registered for use on the minor crop until residue data is collected. The second potential problem involves a chemical which is not economically viable for its major use. This situation might arise if sales volume is simply not great enough to justify continued production, or perhaps to support the cost of providing additional data needed for reregistration. In either case, when production of the chemical stops, its minor uses stop along with the major use.

The third situation arises when a suitable experimental compound has been identified, but potential sales are not great enough to induce a producer to bear the costs of registration. Finally, there is the situation where no effective pesticide has been identified. This may happen when the pest problem facing producers of a minor crop has not received

attention from industry or academia. In all of the preceding cases, industry lacks incentive to produce minor crop pesticides. If the problem is to be resolved, USDA, State Department(s) of Agriculture, or a grower's association must intervene on behalf of the minor use.

The USDA's Agricultural Research Service helps address this problem though its Interregional Research Project Number 4 (IR-4), located at Rutgers University. The IR-4 program "...provides a mechanism for state agricultural research and extension workers to identify specific pesticides that will meet particular needs on minor crops. These workers will be able to cooperate with others in research and extension to develop the efficacy and residue data necessary to obtain tolerances and secure registrations for minor uses." [42] However, the annual budget for the IR-4 program is about 1.9 million dollars. Brosten (1987) points out that this is less than some agrichemical companies spend on the development of a single pesticide.

Minor crop producers may also have recourse to EPA exemptions allowing non-registered uses in cases where a 'special local need' can be shown to exist. Such exemptions are not permanent, but may be extended for up to 5 years, providing additional time for alternative pest control strategies to be developed.

The 1988 Amendments to FIFRA set up a system of registration and reregistration fees designed to provide EPA with additional resources needed to speed the regulatory process. A one-time reregistration fee may be as high as $150,000 for some active ingredients. Active ingredients used solely for minor agricultural uses, or products with low volume or low profits are exempted from the fees. However, problems may arise if registrants decide to cancel registrations of pesticides used on both major and minor crops. All registrants are subject to an annual product maintenance fee of $425. This fee may rise if substantial numbers of registrations are cancelled.

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42 NRC (1987) p.156

Farm Income and Consumer Price Issues

For much of this century, agricultural policy makers have been trying to increase farm incomes. Numerous reasons have been offered to explain low farm income; imperfect markets, inefficient resource allocation, foreign food self-sufficiency policies, etc. How are farm incomes affected by regulatory actions?

Generally speaking, consumers' demand for all food is price inelastic. This means that a one percent increase in the price of food will result in a less than one percent drop in the quantity of food demanded. Specifically, the demand for citrus products in also price inelastic. [43] For the case of a price inelastic good like orange juice, it can be shown that producer revenues increase in the event of a drop in quantity produced, all else remaining equal. *Under those conditions*, one would expect revenues to the average citrus producer to increase should a production-enhancing pesticide lose its registration. Likewise, consumers would pay more for citrus.

The real world is not so simple. The impact on individual producers would vary according to whether they were using the nematicide originally or not; whether they adopted an alternative pesticide or not; and a myriad of physical and managerial characteristics specific to each farm. Thus, while it might be possible to show that the average grower was better off as a result of some regulatory action, it is not possible to show that every grower will benefit. Further, the above analysis ignores trade implications. Higher prices in the U.S. would likely result in more imports from foreign producers.

The impact on individual consumers would likewise vary, depending on their original usage of citrus products, willingness to shift to other products, income levels, etc. Impacts on both producers and consumers also depend on international markets for citrus products. If Brazilian producers are able to supply sufficient orange juice concentrate to prevent price

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[43] Barse, Ferguson, and Seem (1988) derived own-price elasticities of demand for citrus of -0.546 (±0.136) at the farm level, and -0.660 (±0.165) at the retail level, based on work by George and King (1971) and Huang (1985). An own-price elasticity of demand is said to be inelastic if it is greater than -1.0.

increases in the United States, then orange juice consumers would be unaffected, while producers would experience decreased revenues.

To sum up, effects of pesticide regulation on producers or consumers are difficult to clearly identify and understand. They may not even be possible to analyze after the fact. Also, even if the average producer can be shown to benefit financially from regulation, or the average consumer hurt, it does not mean that all individual members of these groups will experience similar effects.

VIII. Conclusions

It is virtually impossible to discern any economic impacts caused by the EPA's decision to prohibit the use of DBCP and EDB for controlling nematodes attacking Florida citrus. Movements in FCOJ prices appear to be weather-related, while the declining U.S. share of world FCOJ markets appears to be a continuing trend, unrelated to U.S. regulatory activity. The economic impacts were minimal, as had been predicted in EPA's economic analysis.

Nematode control practices have changed. New nematicides were registered for Florida citrus after the DBCP and EDB registration cancellations. DBCP has been replaced, largely with aldicarb and fenamiphos. EDB has been replaced with aldicarb and nematicides containing 1,3-dichloropropene.

While chemicals are still important in controlling Florida citrus nematodes, non-chemical methods for mitigating the effects of burrowing nematodes have been developed. Attitudes about nematode control have also changed. Extension nematologists who once touted the benefits of chemical control and dreamed of eradicating soil pests now speak of learning to live with nematodes. In light of the number of nematicides currently under Special Review, this attitudinal innovation may prove to be as important as technological innovation in the fight against nematodes.

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